

## Original Research Article

# Assessment of proximal tibial morphology and its association with anterior cruciate ligament injury: a magnetic resonance imaging-based comparative study

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### ABSTRACT

**Background:** Anterior cruciate ligament (ACL) injuries are common in active individuals and may be influenced by proximal tibial morphology. Increased posterior tibial slope (PTS) is linked to greater ACL strain and higher injury risk. This study aims to assess the association between proximal tibial morphology and ACL injury using magnetic resonance imaging (MRI) in a North Indian population.

**Methods:** A hospital-based cross-sectional study was conducted in the Orthopaedics Department of a tertiary care hospital in North India from November 2022 to January 2024. Eighty patients aged 20-60 were enrolled, divided into ACL injury (cases) and non-injury (controls) groups. MRI was used to assess proximal tibial morphology, focusing on PTS. Data were analyzed using unpaired t tests, Chi-square tests, logistic regression, and Pearson's correlation. A  $p < 0.05$  was considered statistically significant.

**Results:** Most ACL injuries occurred in the 30-45 age group (45%), with fewer in 45-60 group (12.5%). Males were more affected (58%) than females (42%). Overweight individuals made up 72.5% of ACL cases. Posterior tibial medial slope showed no significant association with ACL injury (OR=1.150,  $p=0.882$ ), while lateral slope showed a trend toward a protective effect (OR=0.135,  $p=0.093$ ). Correlation analysis revealed a weak positive correlation for medial slope ( $r=0.024$ ) and a moderate negative correlation for lateral slope ( $r=-0.190$ ).

**Conclusions:** ACL injuries were more frequent in younger, overweight males. Lateral tibial slope showed a potential link to injury risk, suggesting proximal tibial morphology may influence ACL injury.

**Keywords:** ACL injury, Posterior tibial slope, Proximal tibial morphology, MRI, Knee biomechanics

### INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most frequent knee injuries, particularly in physically active individuals, and are associated with long-term instability and early-onset osteoarthritis.<sup>1</sup> Multiple factors contribute to ACL injury risk, including neuromuscular control, hormonal influences, activity patterns, and anatomical variations.<sup>2</sup> Among anatomical factors, the morphology of the proximal tibia-especially the PTS-has been identified as a significant contributor to ACL injury.<sup>3</sup>

An increased PTS is believed to facilitate anterior tibial translation during weight-bearing, increasing strain on the ACL and predisposing to rupture.<sup>4</sup> Both medial and lateral tibial slopes have been implicated in primary ACL tears and graft failures after reconstruction.<sup>5</sup> A recent meta-analysis confirmed that steeper PTS values are significantly associated with a higher risk of ACL injury and re-injury.<sup>6</sup> Given the biomechanical role of the proximal tibia in knee stability, understanding its morphology is essential for early identification of high-risk individuals and for informing preventive and surgical

strategies. This study aims to assess the association between proximal tibial morphology and ACL injury using MRI in a North Indian population.

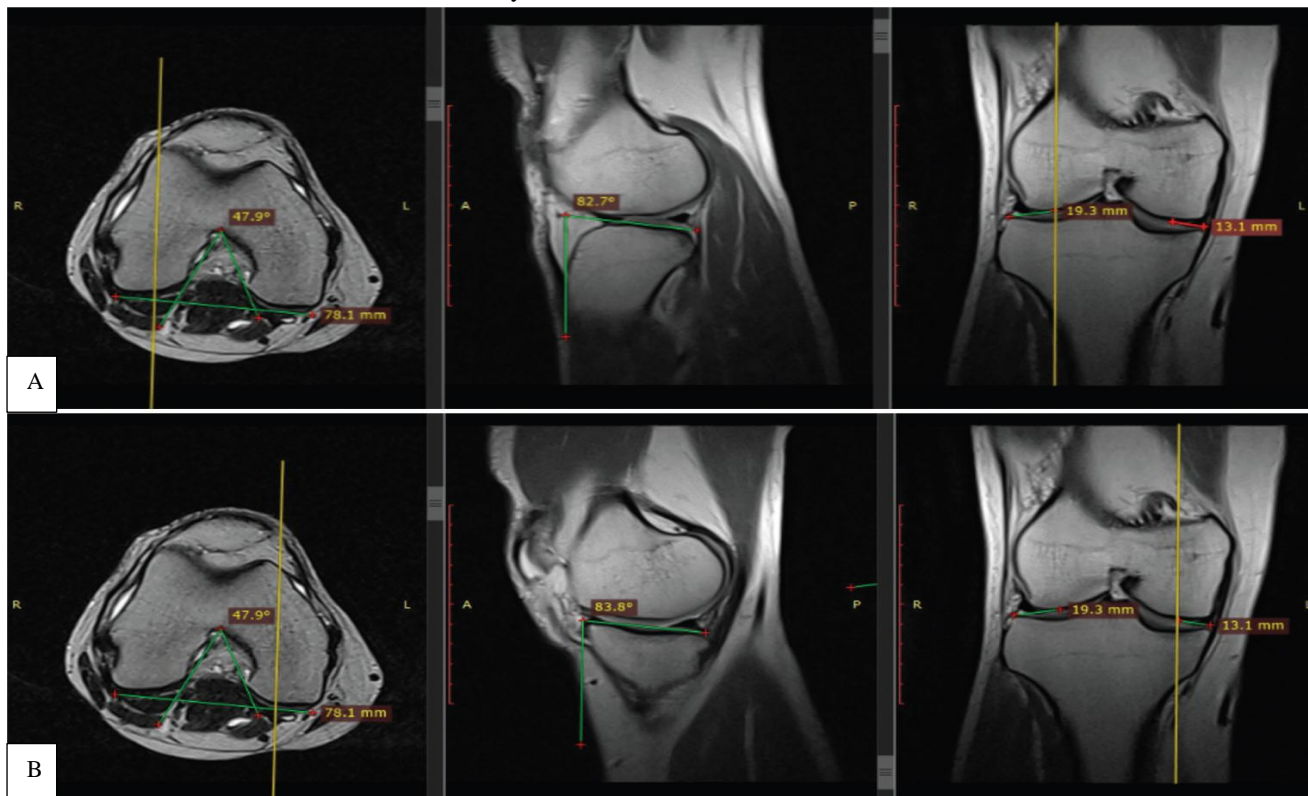
**METHODS**

Hospital-based cross-sectional observational study was conducted in the Department of Orthopaedics at tertiary care hospital north India. The study received ethical clearance from relevant institutional committees, and data collection was carried out from November 2022 to January 2024. The study included patients aged 20 to 60 years attending the orthopaedics outpatient department, divided into two groups: those with isolated ACL injuries (cases) and those without ACL injuries (controls). A total of 80 participants (40 in each group) were recruited consecutively until the sample size was reached. Inclusion criteria comprised adult patients within the specified age range who gave informed consent. Exclusion criteria included patients with other ligamentous injuries, intra-articular knee fractures, arthritis, or a history of ACL

reconstruction. MRI was used to assess proximal tibial morphology. Parameters measured included the PTS, using standard sagittal plane images.

**Measurement of PTSs**

Due to the inability to determine the limb's long axis on standard MRI (unlike CT), we developed a modified technique for measuring PTS. First, the axial image showing the largest femoral popliteal groove was used as a reference. From the corresponding coronal view, midpoints of the medial and lateral articular surfaces were identified. These were defined from the femoral condyle to the respective tibial spine edges. Corresponding sagittal images were then used to measure the slope. On each, a vertical line was drawn along the anterior tibial cortex, and a second line connected the anterior and posterior peaks of the tibial plateau. The angle between these lines represented the PTS for the medial and lateral compartments (Figure 1).



**Figure 1 (A and B): Illustrating the method used to measure (A) PTS in the lateral compartment (B) PTS in the medial compartment.**

Statistical analysis included means and standard deviations for continuous variables (analyzed using unpaired t-tests) and proportions for categorical variables (analyzed using Chi-square or Fisher's exact test). Multiple logistic regression assessed proximal tibial morphology associations with ACL injury. Pearson's correlation evaluated relationships between ACL injury and proximal tibial morphology. A  $p < 0.05$  was considered statistically significant.

**RESULTS**

In Table 1, the age groups, the majority of patients with ACL injuries fall into 30-45 age range (45%), while minority is in 45-60 age group (12.5%). Conversely, patients without ACL injuries primarily fall within the 30-45 age group (60%), with a minority in 15-30 age group (17.5%). Regarding gender, majority of patients with ACL injuries are male (58%), while minority are female (43%).

In case of patients without ACL injuries, there is a more balanced distribution, with a majority being male (50%) and female (50%).

When looking at height, majority of patients with ACL injuries are in 159.7-169.7 cm range (45%), while a minority fall into 179.7-189.7 cm category (2.5%). For patients without ACL injuries, the majority also falls within the 149.7-159.7 cm range (50%), with no individuals in 179.7-189.7 cm group. In terms of weight, majority of patients with ACL injuries are in 65-74 kg range (57.5%), while minority fall in 45-54 kg category (2.5%). Similarly, majority of patients without ACL injuries are also in 65-74 kg range (60%), with a minority in 75-84 kg group (2.5%). Lastly, for BMI, majority of patients with ACL injuries are classified as overweight (72.5%), while minority are underweight (2.5%). For patients without ACL injuries, majority are still overweight (62.5%), while none fall into underweight category. Table 2 highlights the importance of considering the posterior tibial medial slope when assessing the risk of ACL injury. The findings suggest that there is a trend towards increased ACL injury risk in patients with certain ranges of slope measurement, particularly around 7.6-8.1 degrees. However, more research is needed to fully understand the relationship between posterior tibial medial slope and ACL injury risk (Figure 2).

Table 3 explains distribution of patients across different ranges of posterior tibial lateral slope, it can be inferred

that there is a higher likelihood of ACL injury in patients with a posterior tibial lateral slope between 6.8-7.3 degrees. However, the data also indicates that ACL injuries can occur across different ranges of slope measurement (Figure 3). Table 4 presents the correlation coefficients indicating the relationship between PTSs and ACL injury. The posterior tibial medial slope shows a very weak positive correlation ( $r=0.024$ ) with ACL injury, while the posterior tibial lateral slope demonstrates a moderate negative correlation ( $r=-0.190$ ). These findings suggest that neither slope shows a strong association with ACL injury. However, the lateral slope exhibits a comparatively stronger correlation than the medial slope, indicating a slightly more notable relationship with ACL injury risk.

Table 5 summarizes the findings of a multiple logistic regression analysis evaluating the association between ACL injury and selected anatomical factors. The posterior tibial medial slope yielded an odds ratio of 1.150 with a  $p=0.882$ , indicating no significant relationship with ACL injury. The 95% confidence interval ranged from 0.181 to 7.315, and the standard error was 0.944.

In contrast, the posterior tibial lateral slope showed an odds ratio of 0.135 with a  $p=0.093$ , suggesting a potential protective effect, although this did not reach statistical significance. The wide confidence interval (0.013 to 1.400) and standard error of 1.192 reflect substantial variability.

**Table 1: Demographic distribution of different variables between both the groups.**

Variables	Patients with ACL injury		Patients without ACL injury		
	N	%	N	%	
Age groups (in years)	15-30	17	42.50	7	17.50
	30-45	18	45.00	24	60.00
	45-60	5	12.50	9	22.50
Gender	Male	23	58	20	50
	Female	17	43	20	50
Height (cm)	149.7-159.7	17	42.50	20	50.00
	159.7-169.7	18	45.00	18	45.00
	169.7-179.7	4	10.00	2	5.00
	179.7-189.7	1	2.50	0	0.00
Weight (kg)	45-54	1	2.50	0	0.00
	55-64	14	35.00	15	37.50
	65-74	23	57.50	24	60.00
	75-84	2	5.00	1	2.50
BMI (kg/m <sup>2</sup> )	Normal weight	10	25	15	37.50
	Overweight	29	72.50	25	62.50
	Under weight	1	2.50	0	0

**Table 2: Prevalence of PTMS (degree) among patient with ACL injury and non-ACL injury.**

Posterior tibial medial slope (degree)	Patients with ACL injury		Patients without ACL injury	
7.1-7.6	4	10%	1	2.5%
7.6-8.1	25	62.5%	33	82.5%
8.1-8.6	11	27.5%	6	15%

**Table 3: Prevalence of PTMS (degree) among patient with ACL injury and non-ACL injury.**

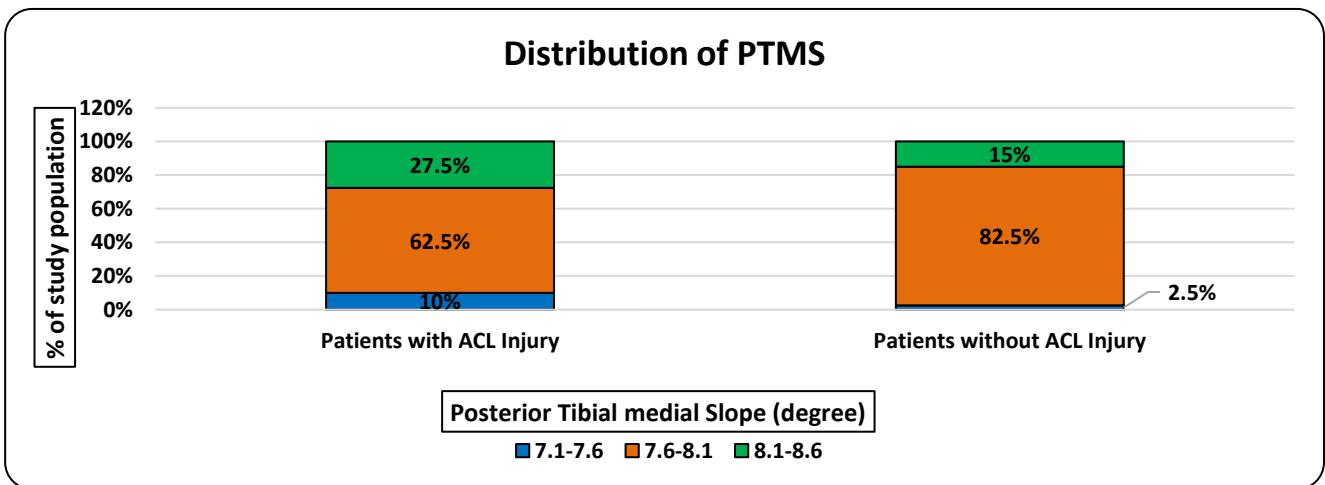
Posterior tibial lateral slope (degree)	Patients with ACL injury		Patients without ACL injury	
6.3-6.8	10	25%	3	7.5%
6.8-7.3	29	72.5%	33	82.5%
7.3-7.8	1	2.5%	4	10%
<b>Total</b>	<b>40</b>	<b>100%</b>	<b>40</b>	<b>100.0%</b>

**Table 4: Correlation between ACL injuries and PTMS/PTLS among the study population.**

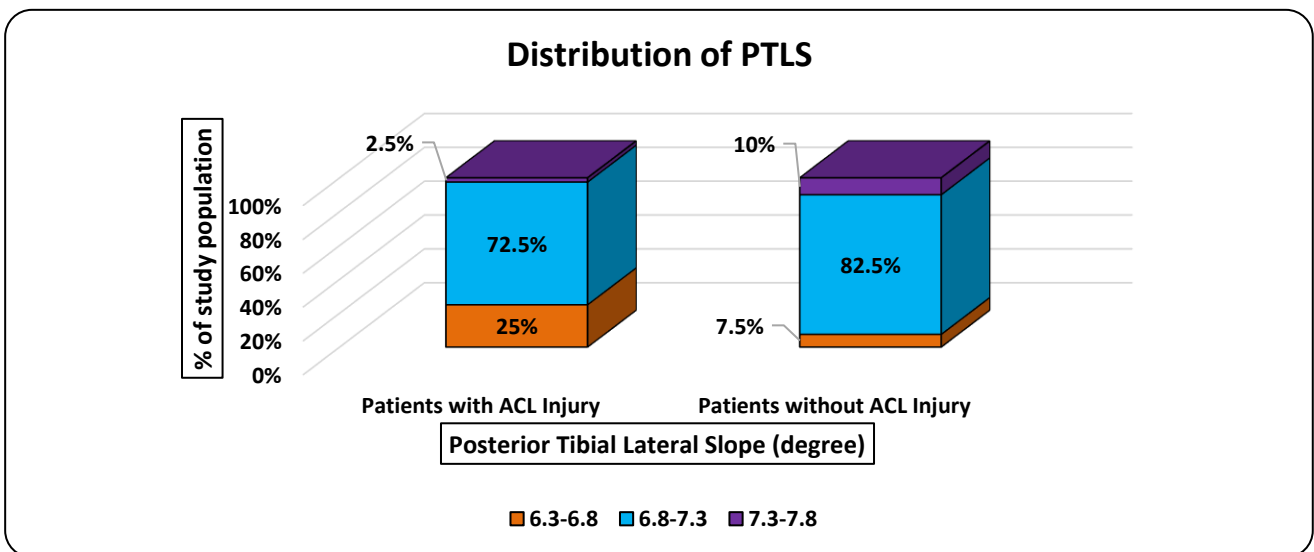
Posterior tibial morphology	Person correlation coefficient of ACL injury
Posterior tibial medial slope (degree)	0.024
Posterior tibial lateral slope (degree)	-0.190

**Table 5: Multiple logistic regression between ACL in injury and associated factors.**

Variables	Odds ratio	P value	S.E.	95% CI	
				Lower	Upper
Posterior tibial medial slope (degree)	1.150	0.882	0.944	0.181	7.315
Posterior tibial lateral slope (degree)	0.135	0.093	1.192	0.013	1.400



**Figure 2: Prevalence of PTMS (degree) among patient with ACL injury and non-ACL injury.**



**Figure 3: Prevalence of PTMS (degree) among patient with ACL injury and non-ACL injury.**

## DISCUSSION

This study explored the association between proximal tibial morphology and ACL injury. A higher frequency of injuries was observed in younger, active individuals, consistent with reports by Noyes et al, Strickland et al, Imhoff et al and Jenkins et al.<sup>7-10</sup> Male predominance also reflects findings by Granan et al, Horstmann et al and Karpinski et al linking it to higher exposure to physical stress and anatomical factors.<sup>11-13</sup> No significant link was found between height, weight, and ACL injury, aligning with Chouliaras et al and Jenkins et al.<sup>10,14</sup> However, a greater proportion of overweight individuals among ACL-injured patients supports earlier findings suggesting body weight may contribute to injury risk. Posterior tibial medial slope showed no significant association with ACL injury ( $p=0.882$ ). In contrast, posterior tibial lateral slope demonstrated a moderate negative correlation ( $r=-0.190$ ) and approached significance ( $p=0.093$ ), suggesting a possible biomechanical influence. This aligns with findings by Stark, Zeng et al and Imhoff et al who reported that increased tibial slope alters joint mechanics and may predispose to ACL injury.<sup>8,9,15</sup> Though not statistically significant, the trend indicates that lateral slope may influence ACL injury risk.

## CONCLUSION

ACL injuries were more common in younger males and overweight individuals. Posterior tibial medial slope showed no significant association, while lateral slope showed a possible link to injury risk. Proximal tibial morphology, especially lateral slope, may play a role in ACL injury and warrants further study.

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